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Analyzing Requirements for and Designing a Collaborative Tool Based on Functional and User Input

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Analyzing requirements for and designing a collaborative tool based on functional and user input

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Abstract

In flightline maintenance, collaboration is an important factor in the maintainer's quest to complete a difficult or unusual repair. Technology provides a multitude of potential collaborative tools and techniques, and this must be balanced against the requirement to leverage and/or support maintainers' existing interaction skills, rather than requiring them to adapt to the technology. This paper discusses the definition of collaboration, a high-level classification of collaboration types, followed by a discussion of the strategy used by the Aircraft Maintenance Intuitive Troubleshooting (AMIT) research project design team to determine the appropriate collaboration tools for the AMIT job aide. In general, this strategy utilized a blend of research and user feedback, balanced by end use environment constraints and requirements, to create a usable and useful collaboration capability for the Air Force maintenance technician.

Introduction

In most jobs, the ability to collaborate with other people at specific points during a task is essential in completing the task correctly. Even cognitively simple tasks that are typically accomplished by a single individual may

require communication at the beginning to fully understand the requirements and goals essential to successful task completion. The requirement for collaboration increases with the complexity of the task. In the case of aircraft maintenance troubleshooting, where large amounts of knowledge and skill are required, few technicians possess all the knowledge necessary to solve all possible scenarios. In fact, as part of our research, expert maintainers have stated that contacting another technician for advice is a logical (and often necessary) step in solving very difficult problems.

The Air Force Research Laboratory has embarked on a research project exploring ways to develop an advanced job aid for flightline maintenance to help technicians solve difficult problems. The Aircraft Maintenance Intuitive Troubleshooting (AMIT) project is a three -year Proof-of-Concept effort headed by the Logistics Readiness Branch, Warfighter Readiness Research Division, Human Effectiveness Directorate (HEAL) through NCI Information Systems, Inc, with the support of its subcontractor, the University of Dayton Research Institute (UDRI). As a job aid for the flightline maintenance technician, AMIT's goal is to support aircraft maintenance technicians by providing them the right

information, appropriate to their experience level, so they will more efficiently and effectively complete their task. A successful AMIT project will be achieved when a novice maintainer's performance can be brought to (or near) the level of an expert maintainer, and when an expert maintainer has demonstrated an improvement in accuracy and time to complete when using the AMIT capability. These performance improvements at the individual level will aggregate to an improved level of maintenance performance at the squadron, wing, and Air Force levels. AMIT will accomplish its goal through a number of methods, such as rendering of technical data and instructions, autonomic search queries, and capturing of maintenance actions and strategies for reuse. However, another important aspect we discovered through our research was the capability to collaborate with other technicians, especially when a difficult repair is not covered by the maintenance technical data.

In flightline maintenance, collaboration is an important factor in the maintainer's quest to complete a difficult or unusual repair. Technology provides a multitude of potential collaborative tools and techniques, and this must be balanced against the requirement to leverage and/or support maintainers' existing interaction skills, rather than requiring them to adapt to the technology. This paper discusses the definition of collaboration, a high-level classification of collaboration types, followed by a discussion of the strategy used by the AMIT design team to determine the appropriate collaboration tools for the AMIT job aide. In general, this strategy utilized a blend of research and user

feedback, balanced by end use environment constraints and requirements, to create a usable and useful system for the Air Force maintenance technician.

Collaboration Definition

Collaboration involves the exchange of information between two or more parties. A foundation for collaborative system design is cited in Tolmie and Boyle (2000), who identify the two components necessary for a collaborative system: information in and information out. Coleman and Ward (2001) go further by suggesting that the benefits of collaboration will be realized only if three elements converge: context, content, and process. Without a common *context*, that is, a common conceptual framework and language, it is difficult to transfer information (*content*) through interpersonal interactions. There must also be a way (*process*) for all participants to collaborate and communicate about this specific, shared content. In short, any given collaborative technology must facilitate the convergence of content, context and process within the digital collaborative workspace.

Once the variables have been addressed, the goal of collaboration is to facilitate understanding and the effective transfer of knowledge. Espinosa et al (2002) use the term *shared mental models* to describe the combined benefits of shared task knowledge and shared knowledge of the participants. Dourish and Berlotti (1991) help provide a framework for this, specifically, whether the information is *explicitly generated*, directed and separate from the shared work object; or *passively collected and*

distributed, and presented in the same shared work space as the object of collaboration. The latter mechanisms are frequently restricted to systems in which all collaborators are virtually co-present and working at the same time. However, Dourish and Berlotti feel there is no need for this restriction, but rather emphasize the object of collaboration as the driving factor.

In AMIT's case, the participants are pre-defined (the maintainer is collaborating with an expert), so the focus can be directed to task knowledge. Thus, as per Espinosa's criteria, collaboration via AMIT can focus on the characteristics of the task that both parties need to know about. Further, the criteria presented by Dourish and Berlotti imply that any collaborative capability used by AMIT needs to incorporate information about the aircraft in some form for use as a reference point. Such shared feedback overcomes problems with informational and role-restrictive approaches. In particular:

1. Shared feedback reduces the costs to individuals of information production by collecting information passively and avoiding restrictions on activities.
2. Shared feedback allows participants to look for and extract the awareness information which is most relevant to them.
3. Shared feedback presents awareness information through the shared workspace and links to it, so that users can
 - a. find relevant information along with the shared object, and
 - b. browse awareness information and the work object concurrently.

While the above list seems to indicate the need for high-fidelity during real-time collaboration, appropriate feedback may not involve interpersonal communication (e.g., facial expressions, hand gestures), but rather information about the task. Kraut (2002) states:

The interactions between the fidelity of shared visual space and the task manipulations demonstrate the importance of understanding the task when determining the value of a shared visual space.... [T]he utility of a shared visual space depends in part on the visual complexity of the task. In settings with many objects in a variety of spatial relationships to one another (e.g., medical setting, aircraft repair), visual space may be particularly important. For less complex visual tasks, especially those in which objects and spatial relationships are static and easily lexicalized, an audio-only connection may suffice.

Categorizing Collaborative Techniques

Kraut's words touch on the issue of practicality; that is, the need to quantify technological capabilities that would actually work in the targeted end-use environment. To translate that quantification into a system design requires codifying the collaboration events into differing event types, each with their own unique needs and constraints. Three general categories of collaboration techniques were identified for the AMIT project; however, they are general enough to provide a categorical checklist for any evaluation of a collaborative capability. These categories, described in detail below,

are: 1) Live Transmission; 2) Message Based; and 3) Archived Messages.

Type 1: Live Transmission: Also known as synchronous collaboration (Dourish & Berlotti, 1991), live transmission is a collaboration event occurring in real time and addressing a specific task. The conveyance of knowledge is qualified by environmental and emotional cues, which may be of equal importance to the information conveyed. The communication is with a limited number of individuals, and time is a critical element. A telephone is a typical example of this type of collaboration event. The tone of voice and background sounds are cues additional to any technical information conveyed.

The following requirements were identified for a Live Transmission collaborative capability:

- Presence awareness of who can be currently contacted.
- Awareness of what mediums can be used with the contact.
- Routing engines that deliver the transmission to the correct party.
- Limited need: not likely required for a high percentage of collaborative situations.
- Audio/Video (A/V) mediums are preferred, text based systems such as Instant Messaging are less desirable.
- Broader bandwidth to support real-time speeds and the wider bandwidth needs of A/V mediums.
- Quality of A/V medium depends on the cues needing to be conveyed. Audio will suffice when video cues are not required.
- Contact pool can be smaller for type 1 because the information needed in

real time is more specific than near-real time.

- Do not require storage systems.

Type 2: Message Based: A message-based collaboration event is an exchange of messages in near real time for the purpose of sharing knowledge about a particular task. The knowledge can be in a question-answer format or purely informational. The assumption in a message-based medium is that a response will come, though not always immediately, and a limited number of responding individuals will be participating. When time is not a critical element and the collaborating parties have multiple tasks to accomplish, message-based collaboration may be the most practical form of collaboration. Further, although not in real time, this form of collaboration can include audio and visual cues. For example, emailing a recorded audio of clicking noise or a picture of corrosion illustrates a common message based collaboration technique. An e-mail is sent to a limited number of individuals and a timely (but not immediate) response is generally expected. When an e-mail is broadcast to a group, and is purely informational without an expected response, it is classified as an archived message event (see below).

Message based systems need the following:

- Presence awareness of who can be currently contacted.
- Awareness of what mediums can be used with the contact.
- Routing engines that deliver messages to the correct party.
- High need and practicality: this collaborative technique should be

accessible from any process and context.

- Do not require real-time communication, but the closer to real time, the more efficient. The slower/older the communication, the less efficient.
- Is task oriented.
- Ideally the message should be supported by A/V mediums, but text will suffice for most message needs.
- May require temporary storage systems.

Type 3: Archived Messages: An archived message is an authored collaboration event intended for a wide audience. An archived copy of a Live or Message Based event that has use beyond a single task can be considered an Archived, or Type 3 event. An archive's purpose is to be a searchable knowledge repository that is not specific to an individual task. Information that is not generalizable, or reusable for other purposes, do not need to be archived. Another goal is to communicate knowledge across time, such as across shifts. A logbook is an example of a Type 3 collaboration event. A logbook provides information to all of its readers the accomplishments of a task that may have relevance to other tasks. In most cases, text will suffice for storage and retrieval. Text extracted from a conversation is sufficient if the cues in the conversation are not important. In cases where cues are important, only the cue needs to be stored and indexed. A two-hour conversation may only contain one still picture and a small amount of text for reuse of the knowledge conveyed.

Archived Message systems need the following:

- Storage systems with maintenance support.
- Access by wide range of individuals.
- Identity systems to control access to the information, and to identify sources storing data for relevance sorting.
- Indexing systems to retrieve relevant information.
- Search systems to query the index.
- Relevance engine to qualify the information retrieved from a search.
- Limited availability. The information is by request, and while high availability is preferred, it is not required.
- Require only enough bandwidth to transmit data one-way, and in near-real time.
- Copies of the data store are sufficient for most tasks.

Collaboration as Applied to AMIT

As stated above, the AMIT job aid is intended to improve the maintainer's ability to successfully accomplish the task at hand: fixing the aircraft. Part of this improvement involves providing capabilities that were either a) not previously available, or b) available in a format that was not optimal. The maintainer's need and ability to collaborate overlaps both a and b. It is the goal of AMIT to provide a collaborative capability that is always available at the point-of-maintenance, as well as optimized for the maintenance environment.

In general, a maintainer will collaborate when the tech data does not provide sufficient information for a successful repair, and the strategy adopted by the maintainer to collaborate depends on what is available. Current modes of

collaboration involve common communication technologies, for example, a phone call or email. However, the state-of-the-art in collaborative technologies clearly includes additional, "higher tech" capabilities, such as instant messaging, real-time digital video, and shared workspaces. A primary challenge faced by the AMIT team was to evaluate and select the collaborative technology(s) most appropriate to the flightline maintenance environment.

The goal of "allowing a subject matter expert to look over the technician's shoulder" seems reasonable; however, technology provides many paths to accomplish this. As the AMIT design team identified several candidate technologies with disparate capabilities, the need for an Aircraft Maintenance User Group (AMUG) for AMIT was identified to evaluate the practicality of these technologies. The AMUG convened for a three day period to specifically address AMIT design issues, including collaboration. Within the topic of collaboration, the AMIT design team sought to identify the following information:

- The parties involved during collaboration,
- Information that is exchanged (format and type),
- Current collaborative techniques and practices,
- Archive and retrieval requirements, and
- Environmental issues.

The parties involved with collaboration were identified as the maintainer and a subject matter expert (SME). The SME may be a technical representative located on-site, or an experienced maintainer

located at a different base. The format of information exchanged can be assumed to have a visual component, or at the very least, a means to reference the technical manuals. However, technology allows the further addition of informational components to the point of excess, or irrelevant, information. Thus, the *type* of information required to successfully collaborate must also be addressed; for example, while technology can allow a video image of the other party's face during a collaborative session, the need for this does not exist. Discussions of location issues assumed that the technician's portion of a collaborative session would be conducted via the AMIT tool, and thus be carried out at the aircraft. Currently, in order to accomplish any form of collaboration, the technician must leave the aircraft and access the collaborative medium at a different location, consuming time for transit and communication away from the flightline -- time that could ideally be spent at the aircraft. Because collaborative sessions are not officially documented in any form, the issue of archiving was addressed. Currently, the maintainer may take notes, or in the case of email, save the emails. However, no standard mechanism exists which would allow future maintainers to access and leverage useful information from previous collaborative sessions. Because the maintainer will be collaborating from the flightline, environmental concerns such as ambient noise were discussed. Finally, the issue of Live Transmission vs. Message Based vs. Archived Messages collaboration was discussed, and the practicality of each was evaluated.

Discussing collaboration requirements with end-users provided real-world context to an array of candidate technologies and thus greatly helped to scope the selection of these technologies for use in the AMIT project. To begin, the AMUG validated that A/V aids in conveying troubleshooting data. For example, audio was identified as good for avionics repair tasks, while video was seen as more relevant for radar. The use of a whiteboard capability was seen as useful for shift change, but not during an actual repair. For documentation purposes, text was considered acceptable for archived collaborative sessions, rather than archiving in the same format that the actual collaboration session used (i.e. archiving video as a video file). Users also agreed that AMIT should integrate collaborative sessions into the logbook. In general, users indicated a willingness to adapt to various collaborative technologies, depending on what is fielded.

Once the AMUG helped the AMIT design team to scope collaboration needs, a second round of evaluation was conducted, involving rapid prototypes of various collaborative capabilities. These Design Consideration Tests (DCTs) were intended to measure time and errors across the combined effects of three levels of task complexity and three levels of collaborative fidelity. The three levels of collaborative fidelity were: 1) Audio, 2) Text, and 3) Text + Visual. The three levels of task complexity were designed to be representative of aircraft maintenance, and required various types of information for successful completion. They were: 1) Simple (involving a yes/no response to a question; 2) Moderate (involving acquiring textual

information and filling out a form), and 3) Difficult (requiring the identification of specific locations on an aircraft). Results of the DCTs verified that, in terms of accuracy, increased task complexity drives the need for increased collaborative fidelity. Specifically, audio was identified as the most error-prone medium across all tasks. However, for task completion time, results indicated that audio was faster than the text and text + visual conditions. It is likely that audio was fastest because it simply did not provide the means to convey all necessary information. The trade-off was quicker, but more error prone, communications. Post-test subjective feedback indicates that participants may have recognized this trade-off, as they felt that they communicated more clearly with the high-fidelity collaborative capabilities (Text and Text/Visual) than with audio.

Conclusion

The AMUG sessions and the DCT results helped identify the scope and performance issues associated with collaboration in the context of flightline maintenance. As a result, the design team was able to make a series of critical decisions involving the scope of the AMIT collaborative capability. First, the need for a visual component is seen as necessary, as is the need for a text-based messaging capability. Also, the ability to transmit voice will be given a high priority, specifically to be used in conjunction with a visually oriented collaborative task. The resulting design should provide a collaborative capability that will be effective across maintenance situations, user experience level, and environment.

However, the road to making these decisions was not easily traveled. One of the biggest challenges faced by the AMIT design team was the fact that so many collaborative technologies currently exist. The design team faced many confrontations between practicality and technology seduction. In the long run, the use of an end-user group (the AMUG) and a performance-based evaluation of candidate capabilities, helped greatly in answering the questions of 1) what is truly needed, 2) what will improve performance, and 3) what would the end-users like. The answers to these questions do not always jibe, however, as illustrated by the mixed results involving the DCTs. In the end, the design team weighed the answers of each and made educated design decisions that will provide the most benefit in terms of improved performance and user acceptance.

References

- Coleman, D. and Ward, L. (2001). *Building Successful Collaborative Solutions*, [White Paper]. San Francisco, CA: Collaborative Strategies LLC.
- Dourish, P. and Berlotti, V. (1992). Awareness and Coordination in Shared Work Spaces. In *Proceedings of the CSCW'92*, pp. 107-114. Toronto, Canada: ACM Press.
- Espinosa, J.A., Carley, K.M., Kraut, R.E., Lerch, F.J., and Fussell, S.R. (August, 2002). The Effect of Task Knowledge Similarity and Distribution on Asynchronous Team Coordination and Performance: Empirical Evidence from Decision Teams. Paper presented at the *Cognitive Research (CORE) Conference*, 2002, Barcelona, Spain.

Kraut, R. E., Gergle, D. and Fussell, S. R. (2002). The use of visual information in shared visual spaces: Informing the development of virtual co-presence. *Proceedings of CSCW'02*, pp. 31-40. NY: ACM Press.

Tolmie, A. and Boyle, J. (2000). Factors influencing the success of computer mediated communication (CMC) environments in university teaching: a review and case study. *Computers & Education*, 34(2), pp. 119-140.